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Modeling of Bolt Behavior Using Finite Element

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ABSTRACT

The failure of bolted connections will present serious economic and human consequences, so it is important to obtain a better understanding of the structural behavior of bolted connections. The objective of this study is to find the best numerical bolt model and analyzing their behavior when subjected to tensile loads. There are three models of bolt will be analyze for this study. First model was analysed using brick element, second model using beam element and the third model bolt using joint element. For this study the finite element software, LUSAS will be used to study various connection models. Convergence study was conducted in this research. For this study, it was found that the brick element is the best model as compared with the beam element and joint element.

Introduction

The threaded fastener (nut and bolts) has played a significant role in the industrial revolution even though the exact date of its conception is not known. Bolted joints are generally made up of the bolt group (head, stud, and nut) and the flange (top and bottom).

Krisnamurthy N. and Graddy E. D. (1976) did a comparative study to correlate the values of critical displacements and stresses obtained using 2-D and 3-D connection models. Thirteen benchmark connections were analyzed. The connections were analyzed elastically, under bolt pretension alone, and under half and full service loads. The correlation factors for results obtained from 2D and 3D model were determined to be 1.4 for displacement and rotation, 1.2 for average stress and 1.8 for maximum stress.

A finite element model that takes into account the plasticity and contact in the steel bolted connections, using the finite element program MEF was presented by Gendron et al. (1989). The 2D model was calibrated against published test results and was shown to correctly predict the behavior of the bolted connection both before and after slip occurrence and can correctly characterize bolt behavior.

Thus a number of experimental as well as analytical studies have been carried out which investigate the behavior of steel connection. Both 2D and 3D finite element models have been employed to understand the behavior of these connections. However a major portion of these studies considered static loading.

Research Methodology

There are three models prepared for this study. There are brick element (Figure 1), beam element (Figure 2) and joint element (Figure 3). The purpose of this study is to identify the best model among the three models. All the models were applied with the same loading and the displacement

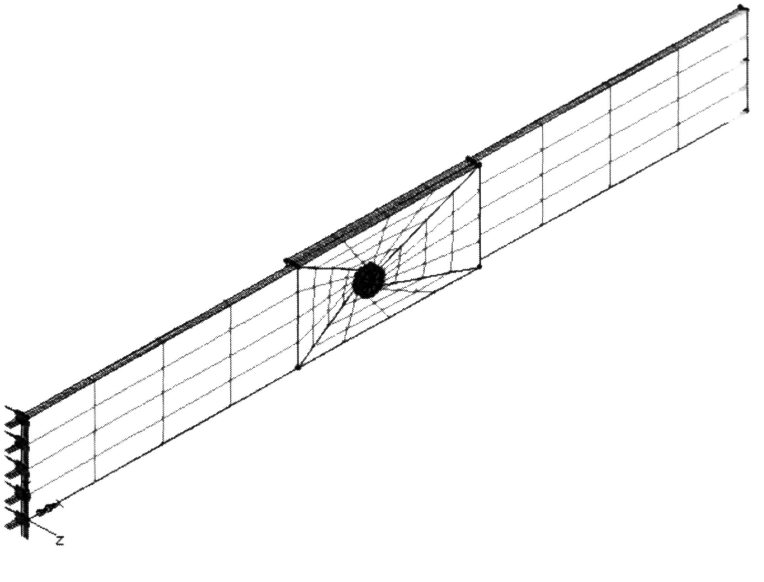

Figure 1: Brick Element Model

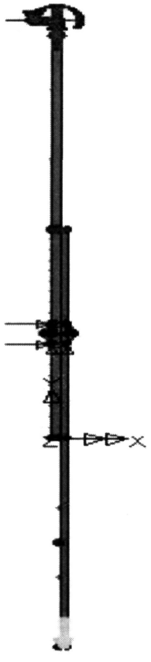

Figure 2: Beam Element Model

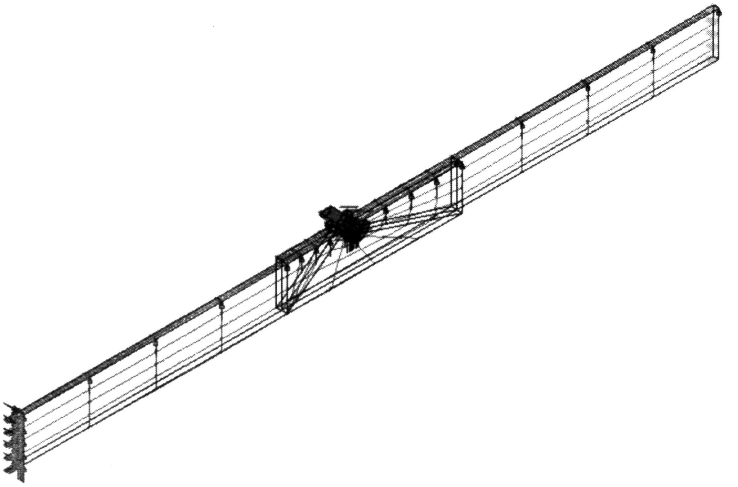

Figure 3: Joint Element Model

were analysed. The model with the least displacement was chosen as a best model. The procedure was conducted as below:

I. Pre processing, enter the data to the program such as geometry, material and boundary condition.

- Material properties = Steel
- Young's Modulus, E = 205 x 10^6 kN/m^2
- Poisson's Ratio = 0.3

II. Solution, where the program computes the finite element solution, and

III. Post processing, where review the results of the analysis through graphics displays and tubular listing.

Results and Discussion

In general, based on maximum displacement/stress against number of meshing for X, Y, and Z direction, the maximum displacement occurs in brick element. The value of maximum displacement in X-direction is 5.405 mm. For beam element, maximum displacement in Y-direction is 0.430 mm. For joint element, maximum displacement in Y-directions is 45.441 mm.

For brick element, the value of maximum stress in X-direction is 2.71 x 10^5 kN/m^2. For beam element, maximum stress in X-direction is 6.44 x 10^5 kN/m^2. For joint element, maximum displacement in X-directions is 2.72 x 10^9 kN/m^2.The results show that the displacements and stress of every element are different based on direction of occurrence and magnitude. The beam element is a surface component analysis. From the beam element analysis the value obtained for displacement and stress in Z-direction is equal to zero. This is because the beam element is two-dimensional, surface element.

Convergence study is should be done to get more accurate results. This can be achieved by adjusting the number of division in meshing section. LUSAS will be run few times until the value of deformed mesh is constant. Table 1 and Table 2 shows the results of displacement and stress obtained from LUSAS varying from one to five number of meshing.

Table 1: Displacement Result for Brick Element, Beam Element and Joint Element

No of Meshing		DX (mm)			DY (mm)			DZ (mm)		
		Brick	Beam	Joint	Brick	Beam	Joint	Brick	Beam	Joint
	Max	0.931	0	2.000	6.883×10^{-3}	0.430	25.192	14.003	0	0.343
1	Min	-0.058	-101.676	0	-6.883×10^{-3}	-1.740	-0.064	0	0	-0.016
	Max	0.909	0	2.764	6.883×10^{-3}	0.108	34.595	19.830	0	0.033
2	Min	-4.796	-25.629	0	-9.445×10^{-3}	-0.439	-8.738×10^{-5}	-0.503	0	-0.016
	Max	5.405	0	3.653	9.445×10^{-3}	0.190	45.441	20.620	0	1.407
3	Min	-0.082	-44.882	-3.945	-9.445×10^{-3}	-0.767	-5.829	-2.055	0	-8.227
	Max	3.015	0	3.653	1.252×10^{-2}	0.190	45.441	25.629	0	0.054
4	Min	-0.106	-44.882	-2.522×10^{-17}	-1.252×10^{-2}	-0.767	-2.845×10^{-4}	0	0	-0.016
	Max	3.015			1.252×10^{-2}			25.629		
5	Min	-0.106^{3}			-1.252×10^{-2}			0		

Table 2: Stress Result for Brick Element, Beam Element and Joint Element

No of Meshing		SX (kN/m²)			SY (kN/m²)			SZ (kN/m²)		
		Brick	Beam	Joint	Brick	Beam	Joint	Brick	Beam	Joint
	Max	1.36×10^{5}	6.44×10^{5}	1.95×10^{9}	3.48×10^{4}	4.03×10^{4}	6.57×10^{3}	2.30×10^{4}	0	1.44×10^{4}
1	Min	-4.10×10^{4}	-7.91×10^{4}	-1.31×10^{9}	-1.72×10^{4}	-2.72×10^{4}	-6.12×10^{3}	-1.25×10^{4}	0	-1.27×10^{4}
	Max	2.02×10^{5}	2.37×10^{4}	2.72×10^{9}	4.98×10^{4}	2.09×10^{4}	5.70×10^{3}	4.54×10^{4}	0	1.83×10^{4}
2	Min	-6.47×10^{4}	-1.96×10^{4}	-3.07×10^{9}	-2.55×10^{4}	-1.27×10^{4}	-5.21×10^{3}	-2.11×10^{4}	0	-1.59×10^{4}
	Max	2.02×10^{5}	3.86×10^{4}	1.07×10^{7}	4.98×10^{4}	3.00×10^{4}	5.44×10^{3}	4.54×10^{4}	0	2.07×10^{4}
3	Min	-6.47×10^{4}	-1.29×10^{4}	-1.10×10^{7}	-2.55×10^{4}	-1.81×10^{4}	-4.85×10^{3}	-2.11×10^{4}	0	-1.75×10^{4}
	Max	2.71×10^{5}	3.86×10^{4}	8.48×10^{8}	6.59×10^{4}	3.00×10^{4}	5.44×10^{3}	6.17×10^{4}	0	2.07×10^{4}
4	Min	-8.69×10^{4}	-1.29×10^{4}	-8.89×10^{8}	-3.48×10^{4}	-1.81×10^{4}	-4.85×10^{3}	-3.06×10^{4}	0	-1.75×10^{4}
	Max	2.71×10^{5}			6.59×10^{4}			6.17×10^{4}		
5	Min	-8.69×10^{4}			-3.48×10^{4}			-3.06×10^{4}		

Conclusion and Recommendation

Based on the results, the best model is the brick element. This is because the value displacement obtained is almost consistent with the value achieved by Jerome Montgomery (2000). The deflection is influenced by the meshing number. The optimum number of meshing is determined firstly to give a consistent deflection through the convergence study. Failure modes of bolts connection observed is yielding in shear which connected the plate. Moreover, the bolt failure is little dependent on the plate thickness that dominates the magnitude of the bending effect.

In the future, the computer should have a large memory with the minimum of 1 GB RAM in order to run the model. This because longer time will be taken to generate and display parameters searched in this study if the memory is low than 512 MB of RAM. h-p adaptive meshing scheme can be used to save more time as the current meshing applied is time consuming.

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